Intensification of oil palm (*Elaeis guineensis* Jacq.) plantation efficiency through planting material:

New results and developments[1]

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ABSTRACT

Indonesia recently pledged to become a major global food producer by boosting the production of food commodities. Palm oil is one of the 10 strategic and key commodities that are part of the government's 2009 – 2014 road-map for food development. Domestic palm oil producers are being encouraged to expand their plantations from the current 7.9 million hectares in 2009 to 9.7 million hectares by 2015. Indonesia goal is to boost CPO production to 36.6 million tonnes per year (Maulia, 2010).

The apparent stagnation of long term palm oil yield trends in the dominant producing countries, such as Malaysia and Indonesia, is considered a vital concern for the oil palm industry and this new agenda makes the intensification of plantation efficiency more necessary, in the context of sustainable palm oil production. Planting material quality has been recognised as a key input for oil palm sustainability. Where the technical efficiency of growers in all the best management practices (BMPs) is optimum, yield enhancement through the improvement of planting materials will remain the main source of economic progress or sustainability (Baskett et al., 2008).

The most recent results from the PT Socfindo Aek Loba Timur Breeding project and their transfer to the commercial plantations accompanied by a stringent selection of the best parental families with a 10 tonnes Total Oil/ha/year target, are presented.

New developments in the PT Socfindo Research & Development programmes such as the implementation of a new selection cycle evaluating the whole parental collection and a new seed garden at the Aek Loba Estate, the development of an early test as a key input in breeding for Ganoderma resistance, or the medium-term search for high-yielding planting material less demanding in fertilizer input are also discussed.

Key words: *Elaeis guineensis, palm oil, breeding, intensification, sustainability, planting material*

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INTRODUCTION

1. The future of palm oil

Indonesia recently pledged to become a major global food producer by boosting the production of food commodities. Palm oil is one of the 10 strategic and key commodities that are part of the government's 2009 – 2014 road-map for food development. Domestic palm oil producers are being encouraged to expand their plantations from the current 7.9 million hectares in 2009 to 9.7 million hectares by 2015. Indonesia's goal is to boost CPO production to 36.6 million tonnes per year (Maulia, 2010).

This ambitious target is also in line with the 2015 Millennium Development Goals adopted by the United Nations General Assembly in 2000 with its core targets of reducing hunger and poverty. But progress appears limited and competition with non-food uses of commodities such as palm oil is endangering the achievement of the Millennium goals. Biofuels based on primary productions such as maize, sugarcane, cassava, soybean and palm oil could increase the competition for suitable soils and endanger food security and food prices (Naylor *et al.*, 2007). For a couple of years, palm oil prices have seemed much more connected to crude oil price trends than to its availability for food consumption (Fry, 2009).

Dietary changes in developing countries from the end of the 20th Century to 2030 are likely to have a dramatic impact on global demand for agricultural products. Instead of meat (+42%) or milk and dairy (+47%), the vegetable oil component is set to increase its proportion in the daily diet of populations in the developing countries by 60%. Consequently, the vegetable oils market should be maintained at a tight level: 45 out of 100 additional kilocalories in the period to 2030 are expected to come from vegetable oils. Countries such as China, India, Mexico and Pakistan should be persistently net importers of vegetable oils (FAO, 2002).

2. Challenges

This apparent stagnation of long term palm oil yield trends in the dominant producing countries, such as Malaysia and Indonesia, is considered a vital concern for the oil palm industry and this new agenda makes the intensification of plantation efficiency more necessary, in a context of sustainable palm oil production (Baskett *et al.*, 2008). The most challenging target for the oil palm industry is without doubt the acceptance of palm oil as a sustainable commodity by consumers in developed countries. Very great pressure is being exerted on the whole oil palm industry and the commodity itself has been stigmatized, particularly in Indonesia (Romandie News, 2009; Greenpeace, 2010a). This pressure is experienced as non-tariff or protectionist barriers by the Malaysian and Indonesian oil palm industry despite the effort to implement sustainable practices through initiatives such as RSPO (Chandran, 2010). Recently, the environmentalist groups apparently modified their targets, returning their attention to the deforestation ban, biodiversity protection and RSPO P&C application (Greenpeace, 2010b).

Obviously, the holistic and systematic application of the RSPO Principles and Criteria could achieve medium and long-term economic viability and maintain responsible environmental and social bottom lines at the same time (Teoh and Tan, 2007). The reduction of the gap between genetic potential and agronomic performances is a further challenge (FAO, 2007; Mukesh, 2007; Donough *et al*., 2009). Such is the case for the commercial sector but it is more dramatic for the small - holder sector, which could account for a very large share of the planted area i.e. more than 40% of the 7.5 million hectares in Indonesia (Suswono, 2010).

The quality of planting material has been recognised as a key input for the palm oil sustainability. Where the technical efficiency of growers in all best management practices (BMPs) is optimum, the enhancement of yield through the improvement of planting materials will remain the main source of economic progress or sustainability (Baskett *et al.*, 2008).

“Increasing palm oil production can be done through utilization better oil palm planting material. Planting material is a critical factor in determining the potential yield per ha. The plant breeders have played a major part in increasing the genetic yield potential of oil palm. They should continue to increase the genetic potential of oil palm planting material through exploiting biotechnology like using the vegetative micro- propagation technique of tissue culture. Oil palm clones are expected to increase yield by some 20-30%.”(Suswono, 2010).

3. Planting material improvement and profitability

The profit margin grows relatively easily with the best management practices (BMPs). It remains difficult to dispose of a simple and clear indicator of the value and quality of planting material (except for the so-called Dari belakang Pondok material or “DP-less”). In spite of everything, where the technical efficiency of growers in all BMPs and IPMs and RSPO P&C are optimum, improvement due to the planting material will remain the sole source of profit margin progress or maintenance. At PT Socfindo, from a genetic potential of 55% achieved in the eighties, the company is now able to achieve up to 70% in the current period (Baskett *et al*., 2008). In at situation of long term declining trend for CPO prices and increasing production costs, increasing the yield progression stabilizes the profit margin in constant USD terms (Baskett and Jacquemard, 2005).

The current uncertain times appear opportune for intensifying the replanting of low yielding palms in order to meet with the joint Malaysian and Indonesian targets to boost average yields from the current 20 tonnes of fresh fruit bunches (FFB) to 35 tonnes expected by 2020 (Chandran, 2010). The way is wide open for breeders to play a major role in promoting Sustainable Palm Oil.

RESEARCH & DEVELOPMENT PROGRAMMES FOR OIL PALM BREEDING AT PT SOCFINDO

1. Introduction

The Socfindo Breeding Programme being implemented with CIRAD support and fully linked with the CIRAD network for more than 30 years is a long story and the results have been regularly presented.

The programme contributes to long-term productivity improvement at PT Socfindo and the other companies of the Socfinal Group. It will allow the company to propose to its customers the best planting material adapted to their needs. The programme takes into account key targets as defined below:

- Develop planting material with a high yield and extraction rate and also:
  - Palms better adapted to specific environmental conditions
  - Resistance to various stress factors such as drought, wind, temperature, etc.
  - Palms better adapted to specific nutrient requirements
  - Resistance to specific diseases and pests, such as *Ganoderma*, *Fusarium* wilt, *Oryctes*, etc.
  - Economic considerations such as fast/slow growth, height increment, high bunch number/low weight or low bunch number/high weight, high extraction/lower bunch weight, sex ratio, CPO/PK ratio, compact palms, etc.
  - Downstream or end-user requirements such as olein / stearin ratio, IV and carotene content, etc
- Produce high-potential planting material from seed

The assigned target is to achieve 1% of genetic improvement per year and transfer the improvement to the commercial planting material through a high quality seed production programme. For that end, it is necessary to conduct around 35 ha of progeny trials and 15 ha of related parental garden per year (Baskett *et al.*, 2008).

The current status of the programme is summarized in Table 1.

Table 1: Current areas used at PT Socfindo for breeding purposes

Breeding programmes	**Area**
Collection, Parental garden	127.98
Ganoderma evaluation (Field test)	491.71
Progeny trials	637.75
Clone tests	63.47
Genomics	24.16
Pisifera certification	21.28
Seed garden	269.03

The collection and parental garden were transferred to Aek Loba Estate in 2004. This includes the transfer of the PSBB collection and the introduction of new germplasm through exchanges with partners such as SRPH Pobé (West Africa), Sumatra Bioscience (Indonesia) or Unilever (Yaligimba – RDC)

A large scale *Ganoderma* resistance evaluation of the Socfindo breeding resources through field tests in a devastated area by *Ganoderma* (Mata Pao, Bangun Bandar and Tanah Gambus estates) occupies up to 490 ha and is evaluating around 1400 connected progenies (2003 – 2009).

Two large projects are specifically dedicated to progeny tests and the evaluation of general combining abilities (GCA): the Aek Loba Timur project with 25 progeny trials (297.79 ha from 1995 to 2000), which is achieving the 9-year-old records for the youngest plantings and the Aek Kwasan II project, started in 2005 currently with 20 progeny trials covering 281.22 ha and 4 more expected for the 2010 / 2011 period. Both of them are being implemented at the Aek Loba Estate.

Two trials, covering 24.16 ha, planted at the Aek Loba Estate in 2003 and 2008, are designed to support genomic studies on key production parameters such as bunch components, FFB components, and growth and canopy characteristics.

Last, but not least, two seed gardens have been opened:

The PSBB seed garden includes 200 ha of A Group garden and 79 ha of B Group garden.

The Aek Kwasan II seed garden is derived from PSBB seed and the parental garden by sib-crossing of the best parents from each family according their own value or their GCA value where available. It covers a current 57.69 ha and is destined to be extended to 110 ha.

An additional programme concerns clone tests and pisifera certification. The total area planted at PT Socfindo for breeding purposes reaches 1635 ha spread across 4 estates.

1.1. Aek Loba Timur Project

The main targets of the Aek Loba Timur project, which was planted from 1995 to 2000, are to continue the breeding work started with the Aek Kwasan genetic block (1970s) and to test the second cycle of parents planted at SRPH Pobé (Benin).

This project comprises 28 trials including 18 progeny trials testing the Pobé parents, 7 progeny trials testing Socfindo genetic resources and 3 clone tests.

Tables 2 and 3 summarize the origin of the tested families. The A Group is represented by 17 families and 142 parents, 27 from Socfindo and 113 from SRPH Pobé (Bénin). The B Group is represented by 26 families and 153 parents from SRPH Pobé (Bénin), CNRA La Mé (Côte d'Ivoire) and Socfindo.

All the trials and all the families are connected. But, some combinations are specific: (TNR115 x LM630D) selfed parents are tested with only dura palms from LM2T and LM2T x LM5T from Socfindo and cannot be compared directly with the other genetic resources. Socfindo A Group x Socfindo B Group combination should also be evaluated separately because the parents involved are not combined with the Pobé parents. This is a key point for the general combining ability studies

Table 2: A Group families tested in the ALT project

Family	Tested parents	Family	Tested parents
(DA5D x DA3D) selfed	18	(TNR115 x LM630D) selfed	11
DA10D x DA115D	8	BB126D x BB150D	9
DA10D x DA3D	7	BB177D x BB129D	3
DA115D second cycle	12	BB206D selfed	4
DA115D selfed	8		
DA115D x DA3D	8		
DA300D x DA128D	7		
DA551D x DA767D	7		
LM269D x DA115D	8		
LM269D x DA128D	16		
LM404D selfed	5		
LM404D x DA10D	6		
LM404D x DA3D	3		

Table 3: B Group families tested in the ALT project

Family	Tested parents	Family	Tested parents
LM2T second cycle	11	BB85T selfed	5
(LM2T x SI10T) selfed	6	BB85T x BB20T	3
LM10T selfed	5	LM238T x LM511P	5
LM2T selfed (PSBB)	7	LM718T selfed	1
LM2T selfed (La Mé)	4	LM718T x LM238T (PSBB)	5
LM2T selfed (Pobé)	16	LM718T x LM238T (Pobé)	5
LM2T x LM5T (PSBB)	6	PO1879T x PO1876T (PSBB)	5
LM2T x LM5T (Pobé)	12	Others	26
LM5T x LM2T (PSBB)	4		
LM5T selfed	11		
LM5T x LM311P	6		

1.2. Aek Kwasan II Project

The planting operations started in 2005. The Aek Kwasan II project is targeting the evaluation of all the Socfindo recombined germplasm and, for the first time in the CIRAD network, all the parents from A Group are to be tested with the B Group parents from both the main sub-groups of families: La Mé origin and Yangambi origin. Each parent from one group should be combined with at least 3 partners from the other group. The design should enable a better evaluation of general combining abilities. Several bridges have been planted for the connection between years in the Aek Kwasan II project, and for the connection with the Aek Loba Timur project and the CIRAD network.

Today, 164 A Group parents from 40 ancestor families are combined with 47 B Group parents from 27 ancestor families or 18 introduced B Group parents from 5 families in incomplete mating and statistical designs.

1.3. Observation

Table 4 summarizes the set of observations carried out in the PT Socfindo genetic trials.

Table 4: Observations carried out in the genetic trials

Type of observation	**Comment**
Census (abnormalities, damage, etc.)	
Monthly	N0 - N1
4 time-a-year	N2 - N3
Twice-a-year	*Ganoderma* (N0 - N11)
Once-a-year	*Ganoderma* (N12 and older)
Once-a-year	Tree file check
Leaf analysis (+ rachis in 2009)	
Per progeny at 3, 5, 7 and 9-years-old	
Global analysis at 4, 6 and 8-years-old	
After 9-years-old: per progeny every 3 years	
Individual recording	
From 3 to 11-years-old except specific cases	Could be extended to 15-years-old for specific cases
Bunch analysis	
From 5 to 6-years-old	
Oil composition	
Iodine value (6-years-old)	
Vertical growth at adult stage	
6, 9 ,12 and 15-years-old	
Vegetative characteristics	
Projected canopy at 9-years-old	
Leaf area at 10-years-old	
Male flowering census	Started in 2002 in the Aek Loba Timur Project on a monthly basis. Weekly basis in the Aek Kwasan II project.

Weekly: 3 to 9-years-old

In the CIRAD / Socfindo network, the results are expressed according to typical codes, a reminder of which is given below:

Planting density: 143 palms per hectare (9 m triangular)

FFB = Fresh Fruit Bunches in tonnes per hectare = FFB per palm (kg) x 135 /1000

% O/Bi = Industrial Oil Extraction rate = %O/B x 0,855

% O/B = Laboratory Oil Extraction rate = % Fruit / Bunch x % Mesocarpe / Fruit x % Oil to Fresh Mesocarp

% KO/Bi = % Kernel / Bunch *0.5*0.893

% TO/Bi = Total Industrial Extraction rate = % O/Bi + % KO/Bi

CPO = Crude Palm Oil per hectare = FFB x % O/Bi

PKO = Palm Kernel Oil per hectare = FFB x % KO/Bi

Total Oil = CPO + PKO

2. Latest results and discussion

The results presented here, concern the 6 to 9- years -old period of the Aek Loba Timur for the crop, bunch quality and growth. The early results (3 to 5- years -old) and young adult stage were presented earlier (Jacquemard *et al*., 2001; Asmady *et al*., 2002; Jacquemard *et al*., 2003). Male flowering has been under observation since 2002, only after the identification of some progenies or clones that were producing very few male inflorescences during the young mature years. Consequently, the data have been analysed from the 5 to 7- years -old observations in the youngest trials, with10 to 12- years -old records for the oldest trials.

The family and parent values, particularly the general combining ability (GCA) have been estimated by the Analysis of Variance module of *X*LSTAT version 02/06/2009 and the module of connected groups creation (Riou and Flori, personal communication).

Because of the specific structure of the Aek Loba Timur Project, parental GCAs are evaluated within 3 groups. Some parents, which are not connected enough, cannot be evaluated.

PSBB Group: the group composition is described in Table 5. The families from the A Group are derived from the Socfindo collection. The families from the B Group come from Côte d'Ivoire (La Mé), Congo (Socfindo and Yangambi) or Nigeria (NIFOR).

Angola origin test group: the mating design of this group is specific compared to the others. The dura used are of La Mé origin and the tenera or the pisifera come from Deli x Angola (A Group). Table 6 summarises the composition of the group.

Pobé group: the group composition is described in Table 7. The families are derived from the Dabou and Socfin (Malaysia) origins. The Group B families come from Côte d'Ivoire (La Mé) and Congo (Yangambi).

Table 5: Families and parents from the PSBB Group

A Group		B Group	
Family	Parents	Family	Parents
BB126DxBB150D BB177DxBB129D BB206Dselfed	9 dura 3 dura 4 dura	LM2Tselfed LM2TxLM269D LM5TxLM2T	1 tenera and 1 pisifera 1 tenera 2 tenera and 1 pisifera
		BB85Tselfed BB85TxBB20P	4 tenera and 1 pisifera 3 tenera
		LM718TxLM238T	3 tenera and 2 pisifera
		PO1879TxPO1876T	3 tenera and 2 pisifera

Table 6: Families and parents from the Angola origin test group

Group A		Group B	
Family	Parents	Family	Parents
(TNR115xLM630D)I	8 tenera and 3 pisifera	LM2Tselfed	5 dura
		LM2TxLM5T	6 dura

2.1. Male flowering capacity

The male inflorescence density was recorded for three years between 2005 and 2007. The corresponding age of the trials varies from 5 to 12- years -old. The risk of low male flowering at very young mature stage (3 to 5- years -old) is not available. We shall therefore be examining the male inflorescence density/ha only.

2.1.1. Family evaluation

Average male flowering reached 5.9 male inflorescences/hectare per observation round over the 3 years of recording (2005 – 2007).

Within the A Group, male flowering is significantly increasing in 4 families, DA115D selfed and DA115D second cycle, LM269D x DA115D and BB206D selfed by 47% on average. Conversely, 3 families are producing a smaller number of male inflorescences, (DA5D x DA3D) selfed, DA10D x DA3D and DA551D x DA767D with a reduction of 35% on average.

Within the B Group, without surprise, Congo (Yangambi) and one Socfindo origin are producing significantly more male inflorescences than the mean of the project (+55%). In general, the typical La Mé families are producing significantly fewer male inflorescences. Some of them, such as LM5T x LM10T or LM5T x LM2T, Nifor family and the recombination LM2T x SI10T appear neutral.

Table 7: Families and parents from the Pobé group

A Group		B Group	
Family	Parents	Family	Parents
(DA5DxDA3D)selfed	16 dura	(LM2T)II	2 tenera and 6 pisifera
DA10DxDA115D	8 dura	LM2Tselfed	4 tenera and 14 pisifera
DA10DxDA3D	7 dura	LM2TxLM10T	5 tenera and 3 pisifera
DA115D II	8 dura	LM2TxLM231T	2 tenera and 2 pisifera
DA115Dselfed	9 dura	LM2TxLM5T	6 tenera and 6 pisifera
DA115DxDA3D	7 dura	LM5Tselfed	5 tenera and 6 pisifera
DA300DxDA128D	7 dura	LM5TxLM10T	5 tenera and 4 pisifera
DA551DxDA767D	7 dura	LM5TxLM311P	4 tenera and 2 pisifera
LM269DxDA115D	8 dura	LM10Tselfed	2 tenera and 3 pisifera
LM269DxDA128D	16 dura	? xLM9T	3 tenera and 2 pisifera
LM404Dselfed	5 dura	FR10	2 tenera
LM404DxDA10D	6 dura	FR9	1 tenera and 3 pisifera
LM404DxDA3D	3 dura	(LM2TxSI10T)I	2 tenera and 4 pisifera
		LM238TxLM511P	3 tenera and 2 pisifera
		LM426Tselfed	2 pisifera
		LM430T selfed	1 pisifera
		LM718Tselfed	1 tenera
		LM718TxLM238T	1 tenera and 4 pisifera

The male inflorescence density/ha appears to be significantly different when the groups of families are analysed separately (Table 8):

The parents derived from the PSBB Group could be compared to those from the Pobé group but not to those from the Angola origin group tests.

2.1.2. Parents from the PSBB Group

In the A Group (Table 9), 3 out of 19 parents are producing on average 36% fewer male inflorescences and 5 are producing on average 29% more male inflorescences. BB206D selfed is confirming its capacity as a good male producer.

In the B Group, the lowest male producers (-37% on average) come from La Mé (3 out of 6 parents) and from Nifor (2 out of 5 parents). The most productive parents for male inflorescence (+ 38%) come from Congo (6 out of 13 parents). BB106T is an illegitimate offspring of LM2T (confirmed by its genetic fingerprint).

2.1.3. Parents from the Angola origin test group

This group has been identified as very low male producer. Within the TNR 115 x LM603D origin, BB5448T could be highlighted as a significantly low male producer (Table 10). Conversely, 2 parents present a greater capacity to produce male inflorescences: BB5450T (TNR115 x LM630D) and BB5506D (LM2T x LM5T).

2.1.4. Parents from the Pobé group

From the A Group families, 11 parents have been identified as low male inflorescence producers: 1 from (DA5D x DA3D) selfed, 4 from DA551D x DA767D and 6 from LM269D x DA128D. On average, their male flowering is reduced by 113%. From the B Group families, 10 parents could be highlighted as low male producers: 3 from LM2T selfed or second cycle, 1 from LM10T selfed, 2 from LM2T x LM5T, 3 from LM5T selfed and 1 from LM5T x LM10T. On average, these 10 B Group parents have a male flowering capacity reduced by 57%. Table 11 summarizes the results.

As regards the best male producers in the Group A, a large majority of the parents have DA115D as one ancestor at least: 2 parents from DA10D x DA115D, 8 parents from DA115D selfed or second cycle, 1 parent from DA115D x DA3D and 8 parents from LM269D x DA115D. Male flowering for the 21 best male producers from the A Group is increased by 76%.

In the B Group, the large majority of the good male inflorescence producers come from Congo (Yangambi) group. Two parents from LM5T x LM10T are highlighted as good male producers: PO2973P and PO4986T. The 18 parents involved have potential male flowering increased by 96%. It would be interesting to confirm later if such outstanding parents (or families) can combine high oil production and non-limiting male flowering.

2.2. Growth

The stem height at 6 and 9- years -old (centimetres) and the annual growth between 6 and 9- years -old (centimetres / year) are presented. The other set of parameters, such as the leaf area and the canopy projection is not complete and does not enable a full evaluation of GCA.

Table 8: Male inflorescence density / ha on a general level and an analysis group level

	General mean	PSBB Group	Angola Group	Pobé Group
Male Inflorescences / ha / round	5.9	6.4	1.0	4.3
	Lowest parent	1.3	-0.5	-3.7
	Highest parent	9.8	3.6	12.9

Table 9: Lowest and highest male producers in the PSBB Group

Lowest male producers			Highest male producers		
A Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
BB126D x BB150D	2 / 9	-66.1 %	BB126D x BB150D	1 / 9	+32.0 %
BB177D x BB129D	1 / 3	-40.0 %	BB206D selfed	4 / 4	+27.7 %
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
LM2T selfed	1 / 2	-79.2 %	BB85T selfed	2 / 5	+41.5 %
LM5T x LM2T	2 / 3	-27.2 %	BB85T x BB20P	1 / 2	+30.2 %
PO1879TxPO1876T	2 / 3	-29.1 %	LM2T x LM269D	1 / 1	+50.5 %
			LM718T x LM238T	3 / 5	+33.8 %

Table 10: Lowest and highest male producers in the Angola origin group

Lowest male producers			Highest male producers		
A Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
(TNR115xLM630D)I	1 / 11	-152.4 %	(TNR115xLM630D)I	1 / 11	+156.4 %
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
			LM2TxLM5T	1 / 6	+258.9 %

Table 11: Lowest and highest male producers in the Pobé group

Lowest male producers			Highest male producers		
A Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
(DA5DxDA3D)selfed	1 /16	-56.5 %	DA10DxDA115D	2 / 8	+73.9 %
DA551DxDA767D	4 / 7	-140.6 %	DA115D II	1 / 8	+84.4 %
LM269D x DA128D	6 / 16	-104.1 %	DA115Dselfed	7 / 9	+67.9 %
			DA115DxDA3D	1 / 7	+60.7 %
			DA300DxDA128D	1 / 7	+49.7 %
			LM269DxDA115D	8 / 8	+88.4 %
			LM269DxDA128D	1 / 16	+80.6 %
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
LM2T II	1 / 8	-51.6 %	(LM2TxSI10T)I	1 / 8	+91.2 %
LM2T selfed	2 / 18	-50.5 %	? xLM9T	2 / 5	+69.8 %
LM2T x LM5T	2 / 12	-60.4 %	FR9	1 / 4	+44.8 %
LM5T selfed	3 / 11	-61.9 %	LM238TxLM511P	4 / 5	+113.4 %
LM5T x LM10T	1 / 9	-54.0 %	LM426Tselfed	2 / 2	+104.3 %
LM10T selfed	1 / 5	-61.0 %	LM430T selfed	1 / 1	+79.5 %
			LM5TxLM10T	2 / 9	+66.6 %
			LM718Tselfed	1 / 1	+114.2 %
			LM718TxLM238T	4 / 5	+114.7 %

2.2.1. Family evaluation

Compared to the project mean (Table 12), the CIRAD network standard cross LM2T x DA10D appears similar for annual growth.

Four A Group families are significantly shorter than the mean of the project: DA115D x DA3D, DA551 x DA767D, (DA5D x DA3D) selfed and LM269D x DA115D at 9- years -old. Two of them show significantly lower annual growth: DA115D x DA3D and (DA5D x DA3D) selfed. They could reduce annual growth by 10%. The effect of DA3D on growth has been well known for years.

On the other hand, four families are confirming their ability to transmit fast growth: DA300D x DA128D, BB177D x BB129D and 2 families derive from LM404D: LM404D selfed and LM404D x DA10D. They are increasing annual growth by 8.5% on average.

For the B Group families, the results are also confirming the general knowledge of how the La Mé and Congo (Yangambi) origins performs. Three specific La Mé families can be highlighted for very slow growth: LM2T selfed or second cycle, LM5T selfed and LM5T x LM311P. They are reducing palm growth by 10.5%.

Two families, BB85T selfed (Congo origin from Socfindo) and LM238TxLM511P (Congo origin from Yangambi) confirm their fast growth. The Nifor family is growing spectacularly fast, inducing an almost 26% increase in annual growth. The general characteristics of the group of families are summarized in table 13:

The PSBB Group is growing around 18% faster than the Project mean. That is due to the over representation of fast growing families such as the Congo (Yangambi and Socfindo) or Nifor origins.

2.2.2. Parents from the PSBB Group

Seven parents from the A Group, 5 from BB126D x BB150D and 2 from BB206D selfed and 9 from the B Group have been identified as slow growth parents (Table 14). The good GCA of 4 out of 5 parents from LM718T x LM238T (Congo Yangambi) can be highlighted. Without surprise, all the pure La Mé parents significantly reduce the growth of their offspring.

Five parents from the A Group have been identified as fast growers (Table 15). Three of them come from BB126D x BB150D. This family shows a highly contrasted figure with 5 parents significantly reducing the growth and 3 parents significantly increasing the growth in their offspring. In the B Group, all the Nifor parents show an extraordinary capacity for fast growth

2.2.3. Parents from the Angola origin test group

From the Angola x Deli family, only one parent has been detected with a GCA reducing growth (Table 16 and 17). There is not any parent that can be highlighted as specifically growing faster than the others.

One parent from LM2T selfed has a very good GCA, reducing the growth rate by 21.5%. Three other parents display a poor GCA, increasing growth by 10 to 12%.

2.2.4. Parents from the Pobé group

Fourteen parents from the A Group show a good GCA for growth (Table 18). Fifty percent of of them come from families already identified in the family analysis (DA5D x DA3D selfed and DA115D x DA3D). Five additional parents have DA115D as one ancestor at least. On average, these 14 parents are reducing the growth rate by 10%.

In the B Group, 21 parents have a good GCA for growth. Quite a large majority comes from the La Mé origin. The recombination La Mé x Sibiti (LM2T x SI10T) is very interesting: 4 out of 5 parents are reducing growth by 16% on average.

On the other hand, 19 parents from the A Group significantly increase growth of their offspring (Table 19). LM404D, like DA300D, is confirmed as an ancestor transmitting fast growth. On average, these 15 parents are increasing growth characteristics by nearly 12%.

In the B Group of families, of the Congo families that it is not surprising to see there, 1 parent from the La Mé x Sibiti recombination appears to be significantly different from the other members of the family. Nine well identified La Mé parents display a poor GCA for this character: 2 from LM2T x LM10T, 1 from LM2T x LM5T, 2 from LM5T selfed and 4 from LM5T x LM10T. This sub-group increases growth by 8.7%, compared to 14.1% for the rest of fast growing parents.

Table 12: Comparison of the growth characteristics between the project and the standard cross

	LM2T x DA10D	ALT project
Height at 6- years -old	174.4	183.5
Height at 9- years -old	344.7	353.7
Annual growth 6 to 9- years -old	56.8	56.7

Table 13: Stem increment characteristics of the groups of families

	General mean	PSBB Group	Angola Group	Pobé group
Height at 6- years -old	183.5	212.2	189.9	171.3
	Minimum	157.0	173.5	125.6
	Maximum	262.7	197.4	214.0
Height at 9- years -old	383.7	403.2	344.3	330.5
	Minimum	312.3	306.8	246.9
	Maximum	516.2	367.6	418.8
Annual growth 6 to 9- years -old	56.7	63.7	51.2	53.1

	Minimum	51.4	40.4	37.5
	Maximum	85.0	58.1	68.3

Table 14: GCA of the slow growing parents in the PSBB Group (%)

Family	Parents	Height at 6- years -old	Height at 9- years -old	Annual growth 6 to 9- years- old
A Group				
BB126D x BB150D	5 / 9	-4.3 %	-5.1 %	-6.1 %
BB206D selfed	2 / 4	-7.0 %	-6.5 %	-5.8 %
B Group				
LM2T selfed	2 / 2	-19.9 %	-19.5 %	-19.0 %
LM5T x LM2T	3 / 3	-17.2 %	-17.3 %	-17.5 %
LM718T x LM238T	4 / 5	-1.6 %	-4.2 %	-7.1 %

Table 15: GCA of fast growing parents in the PSBB Group (%)

Family	Parents	Height at 6- years -old	Height at 9- years -old	Annual growth 6 to 9- years -old
A Group				
BB126DxBB150D	3 / 9	+4.2 %	+6.1 %	+8.2
BB177DxBB129D	2 / 3	+10.7 %	+9.7 %	+8.6 %
B Group				
BB85Tselfed	3 / 5	+6.4 %	+9.0 %	+12.0 %
BB85TxBB20P	1 / 3	-3.0 %	+1.4 %	+6.3%
PO1879TxPO1876T	5 / 5	+18.5 %	+17.2 %	+15.2 %

Table 16: GCA of slow growing parents in the Angola origin test group (%)

Family	Parents	Height at 6- years -old	Height at 9- years -old	Annual growth 6 to 9- years -old
A Group				
(TNR115 x LM630D) II	1 / 11	-8.6 %	-10.9 %	-13.6 %
B Group				
LM2T selfed	1 / 5	+2.0 %	-8.5 %	-21.5 %

Table 17: GCA of fast growing parents in the Angola origin test group (%)

Family	Parents	Height at 6- years -old	Height at 9- years -old	Annual growth 6 to 9- years -old
B Group				
LM2T selfed	1 / 5	+4.0 %	+6.8 %	+10.3 %
LM2TxLM5T	2 / 3	+1.9 %	+5.8 %	+11.9 %

Table 18: GCA of the slow growing parents in the Pobé group (%)

Family	Parents	Height at 6- years -old	Height at 9- years -old	Annual growth 6 to 9- years -old
A Group				
(DA5DxDA3D)selfed	4 / 16	+0.1 %	-4.3 %	-9.0 %
DA10DxDA115D	1 / 8	-3.3 %	-5.4 %	-7.8 %
DA115D II	1 / 8	-3.7 %	-10.3 %	-17.3 %
DA115Dselfed	3 / 9	-2. 8 %	-5.4 %	-8.2 %
DA115DxDA3D	3 / 7	-5.3 %	-7.1 %	-9.1 %
DA551DxDA767D	1 / 7	-14.2 %	-16.3 %	-18.5 %
LM269DxDA128D	1 / 16	-6.3 %	-9.4 %	-12.7 %
B Group				
(LM2TxSI10T)I	5 / 6	-15.8 %	-15.9 %	-16.2 %
FR9	1 / 4	-20.9 %	-15.6 %	-9.9 %
LM2Tselfed	6 / 18	-12.3 %	-12.5 %	-12.7 %
LM2TxLM10T	2 / 8	-8.4 %	-10.3 %	-12.4 %
LM2TxLM5T	3 / 12	-6.4 %	-7.3 %	-8.2 %
LM5Tselfed	1 / 11	-10.4 %	-9.0 %	-7.5 %
LM5TxLM10T	1 / 9	-10.6 %	-9.6 %	-8.6 %
LM5TxLM311P	2 / 6	-7.1 %	-8.5 %	-10.0 %

Table 19: GCA of the fast growing parents in the Pobé group (%)

Family	Parents	Height at 6- years -old	Height at 9- years -old	Growth between 6 to 9- year -old
A Group				
DA10DxDA115D	5 / 8	+7.6 %	+9.0 %	+10.5 %
DA10DxDA3D	1 / 7	+6.4 %	+6.3 %	+6.1 %
DA300DxDA128D	2 / 7	+2.3 %	+5.0 %	+7.9 %
DA551DxDA767D	1 / 7	-1.9 %	+9.4 %	+21.5 %
LM269DxDA115D	2 / 16	+8.4 %	+8.6 %	+8.8 %
LM404Dselfed	3 / 5	+12.5 %	+12.3 %	+11.9 %
LM404DxDA10D	4 / 6	+11.5 %	+13.2 %	+15.1 %
LM404DxDA3D	1 / 3	+11.9 %	+12.6 %	+13.4 %
B Group				
(LM2TxSI10T)I	1 / 6	+12.6 %	+11.3 %	+10.0 %
? xLM9T	1/ 5	+4.2 %	+6.5 %	+9.0 %
FR10	1 / 2	+8.1 %	+13.4 %	+19.1 %
FR9	1 / 4	+0.4 %	+5.2 %	+10.4 %
LM238TxLM511P	3 / 5	+16.8 %	+17.5 %	+18.2 %
LM2TxLM10T	2 / 8	+7.6 %	+8.4 %	+9.2 %
LM2TxLM5T	1 / 12	0.0 %	+2.6 %	+5.4 %
LM426Tselfed	2/ 2	+12.7 %	+14.3 %	+15.9 %
LM430T selfed	1 / 1	+24.8 %	+20.3 %	+15.4 %
LM5Tselfed	2 / 11	+3.3 %	+5.1 %	+7.0 %
LM5TxLM10T	4 / 9	+7.1 %	+ 8.6 %	+10.1 %
LM718TxLM238T	3 / 5	+ 12.6 %	+13.0 %	+13.5 %

2.3. Ganoderma

The Aek Loba Timur project has been planted on a second generation of oil palm. The evaluation of *Ganoderma* spread is carried out through regular censuses twice a year. Fortunately for the evaluation of other parameters, the spread of the disease remains limited and does not allow a precise evaluation of the GCAs for susceptibility to or resistance for *Ganoderma*. Nevertheless, some indications can be highlighted.

2.3.1. Family evaluation

The number of palms affected by *Ganoderma* disease reaches 5.1 % on average in the project, all planting years combined.

The information collected on family level is confirming our current knowledge. Two families in the A Group (DA300D x DA128D and LM269D x DA115D) and 3 families in B Group (LM5T x LM10T, FR9 and LM2T x LM269D) can be assessed as globally susceptible.

The largest fluctuation in *Ganoderma* spread is recorded in the Pobé group, as shown in table 20. The difference between the Angola Group and the others is due to the age of the trials in which the Angola origin material is being tested (1999 planting only).

2.3.2. Parents from the PSBB Group

No parents from the A Group can be detected with a good or bad GCA (Table 21). In the Group B, only 1 parent from BB85T x BB20P displays a good GCA and the single parent from LM2T x LM269D is confirmed as having a very bad GCA for *Ganoderma* resistance.

2.3.3. Parents from the Angola origin test group

It is the same case for the A Group within the Angola origin test group (Table 22). No parent can be detected. For the B Group, one parent from LM2T x LM5T can be highlighted with a good GCA and one parent from LM2T selfed with a bad GCA.

2.3.4. Parents from the Pobé group

Four parents from 4 different A Group families and 3 parents from 3 different Group B sources have been identified with a good GCA (Table 23).

On other hand, five parents from the A Group and 7 from the Group B are showing a poor GCA for *Ganoderma* resistance. In some cases, potentially susceptible and resistant parents come from the same family such as DA115D x DA3D and DA300D x DA128D. It is also important to point out, that the difference between parents displaying good GCA and poor GCA must be very large to be significant. That underlines the limitations of such a project which is not specifically designed to evaluate *Ganoderma* resistance. This point should be addressed later.

Table 20: *Ganoderma* spread over groups at Aek Loba Timur Project.

	General mean	PSBB Group	Angola Group	Pobé group
Cumulative *Ganoderma* spread (%)	5.1	4.4	1.6	5.2
	Minimum	0.5	0.0	0.0
	Maximum	9.9	3.7	13.7

Table 21: GCA (%) for *Ganoderma* spread in the PSBB Group

Low *Ganoderma* Spread			High *Ganoderma* Spread		
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
BB85T x BB20P	1 / 3	-88.0 %	LM2T x LM269D	1/1	+123.4 %

Table 22: GCA (%) for *Ganoderma* spread in the Angola origin test group

Low *Ganoderma* Spread			High *Ganoderma* Spread		
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
LM2T x LM5T	1 / 6	-175.9 %	LM2T selfed	1 / 5	+133.3 %

Table 23: GCA (%) for *Ganoderma* spread in the Pobé group

Low *Ganoderma* Spread			High *Ganoderma* Spread		
A Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
DA10D x DA3D	1 / 7	-124.5 %	DA115D selfed	2 / 9	+99.1 %
DA115D x DA3D	1 / 7	-75.2 %	DA115D x DA3D	2 / 7	+105.1 %
DA300D x DA128D	1 / 7	-62.4 %	DA300D x DA128D	1 / 7	+93.2 %
LM269D x DA115D	1 / 8	-97.3 %			
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
LM2T II	1 / 8	-143.9 %	LM2T selfed	1 / 18	+121.5 %
LM5T x LM311P	1 / 6	-132.3 %	LM10T selfed	1 / 5	+161.0 %
LM426T selfed	1 / 2	-116.5 %	LM2T x LM10T	1 / 8	+85.8 %
			LM5T selfed	1 / 11	+124.7 %
			? x LM9T	1 / 5	+164.0 %
			FR9	2 / 4	+85.0 %

2.4. Bunch Quality

As usual, bunch quality is evaluated through a series of bunch analyses made carried out in accordance with the CIRAD standard. Because of the specific structure of the crosses, the Angola x Deli family is not included in the family evaluation. The characteristics presented in this corpus concern the oil extraction rate (O/Bi), the palm kernel extraction rate (KO/Bi) and the Total Oil (TO/Bi).

2.4.1. Family evaluation

The average bunch quality recorded in the project and the standard cross characteristics are summarized in Table 24. The extraction rates for the standard cross are fully comparable to the corresponding values from the CIRAD network. On average, the project is improving standard cross O/Bi by 14.8% and standard cross TO/Bi by 13.5%.

Two families from the A Group significantly improve the mean of the project: LM404D selfed by an additional 6% (O/Bi = 28.3%; KO/Bi = 1.6 % and TO/Bi = 29.9 %) and DA115D selfed by an additional 2% (O/Bi = 26.9%; KO/Bi = 1.8% and TO/Bi = 28.7%).

On the other hand, five families from the B Group, 3 of Congo origin and 2 of La Mé origin, significantly improve the mean of the project (Table 25). For these families, the palm oil extraction rate exceeds 27% and the total extraction rate (palm oil + kernel oil) exceeds 30%.

The materials tested in the Angola origin group display very specific bunch characteristics with large kernels. That is due to the direction of the crosses: the dura is of La Mé origin and the tenera or the pisifera of Angola x Deli origin. The crosses have lost small kernel allele. This allele is linked to the Sh- gene of the La Mé origin and is not present in the other origins (Baudouin, personal communication).

2.4.2. Parents from the PSBB Group

Three parents from the A Group, derived from BB126D x BB150D are significantly improving the extraction rate (Table 27). The 3 parents have outstanding oil content in fresh mesocarp. Two of the three also have excellent mesocarp to fruit content.

For the B Group families, 8 parents, 5 from LM718T x LM238T, 1 from BB85T selfed and 2 from the Nifor family also have a good GCA. Six of the eight parents display outstanding oil to fresh mesocarpe content, compared to three displaying significantly better mesocarp to fruit and fruit to bunch content. In this PSBB Group, oil to mesocarp content appears to be a key criterion significantly improving the extraction rate.

For nearly half of the best parents, a share of the improvement obtained for the palm oil extraction rate is countered, unfortunately, by a loss in the kernel oil extraction rate due to the reduction in the kernel size.

2.4.3. Parents from the Angola origin test group

Two of the three (TNR115D x LM630D) II parents receive an excellent extraction rate from an outstanding fruit to bunch ratio (Table 28). The third is characterized by excellent oil to mesocarp. In the B Group parents, the best from LM2T selfed is remarkable for the fruit to bunch. All the major bunch components (F/B, M/F and O/M) are excellent for the other two parents.

Table 24: Mean bunch quality for the project and the standard cross

	LM2T x DA10D	ALT project
O/Bi %	22.4	26.3
KO/Bi %	1.9	1.9
TO/Bi %	24.3	28.1

Table 25: GCA (%) of the best B Group families for bunch quality

	O/Bi (%)	KO/Bi (%)	TO/Bi (%)
Project Mean	26,3	1,9	28,1
LM238TxLM511P	+6.7 %	+26.3 %	+8.5 %
LM718Tselfed	+4.2 %	+15.8 %	+5.3 %
LM718TxLM238T	+3.8 %	+10.5 %	+5.0 %
LM5TxLM10T	+4.9 %	-21.1 %	+3.6 %
FR9	+4.2 %	-21.1 %	+2.8 %

Table 26: Bunch quality for the three study groups

	General mean	PSBB Group	Angola Group	Pobé group
O/Bi (%)	26.3	26.2	23.2	26.2
	Minimum	22.3	21.4	21.8
	Maximum	28.5	25.8	30.3
KO/Bi (%)	1.9	1.8	2.9	1.9
	Minimum	1.1	2.6	1.2
	Maximum	2.5	3.4	3.0
TO/Bi (%)	28.1	28.0	26.1	28.0
	Minimum	24.7	24.0	24.0
	Maximum	30.8	28.4	32.0

Table 27: Extraction rates of the best parents in the PSBB Group (GCA %)

Family	Parents	O/Bi %	KO/Bi %	TO/Bi %
Group A				
BB126DxBB150D	3 / 9	+5.4 %	-4.2%	+4.8 %
Group B				
LM718TxLM238T	5 / 5	+4.8 %	+17.3 %	+5.7 %
BB85Tselfed	1 / 5	+3.3 %	-2.4 %	+2.9 %
PO1879TxPO1876T	2 / 5	+7.0 %	-31.3 %	+4.5 %

2.4.4. Parents from the Pobé group

Thirteen parents from 6 A Group families improve the mean of the project TO/Bi by 6.6% (Table 29). The expected commercial palm oil extraction rate is close to 28% and the total oil content reaches nearly 30%. Outstanding fruit to bunch content is the major contributor to the extraction rate for 9 parents. That is also the case for 8 parents concerning oil to fresh mesocarp. From the B Group, 24 parents from 7 La Mé families and 4 Congo (Yangambi) families improve the extraction rate of the project by 6.4%. Compared to the previous group, the expected extraction rates are very similar, but for some La Mé parents and families, the switch from kernel oil to palm oil could be important, moderating the final improvement of the expected total oil content. For a majority of parents (50%), their outstanding status comes from one component of the bunch. Thirty percent of the parents have two outstanding components and 8% three.

Table 28: Extraction rates for the best parents in the Angola origin test group (GCA %)

Family	Parents	O/Bi %	KO/Bi %	TO/Bi %
A Group				
(TNR115xLM630D)I	3 / 11	+5.4 %	+1.6 %	+5.5 %
B Group				
LM2Tselfed	1 / 5	+3.4 %	+10.0 %	+4.1 %
LM2TxLM5T	2 / 6	+11.3 %	-11.3 %	+7.3 %

Table 29: Extraction rates for the best parents in the Pobé group (GCA %)

Family	Parents	O/Bi %	KO/Bi %	TO/Bi %
A Group				
DA115Dselfed	2 / 9	+3.7 %	+0.7 %	+3.5 %
DA115DxDA3D	1 / 7	+7.9 %	-2.3 %	+7.3 %
DA300DxDA128D	2 / 7	+4.9 %	-0.9 %	+4.6 %
LM269DxDA128D	4 / 16	+6.1 %	+18.8 %	+7.1 %
LM404Dselfed	3 / 5	+11.6 %	-15.3 %	+9.9 %
LM404DxDA3D	1 / 3	+5.3 %	-4.5 %	+4.7 %
B Group				
(LM2T)II	1 / 8	+5.4 %	-3.6 %	+4.8 %
(LM2TxSI10T)I	2 / 6	+8.1 %	-10.4 %	+6.7 %
? xLM9T	1 / 5	+6.4 %	-7.3 %	+5.5 %
FR10	2 / 2	+7.7 %	-11.2 %	+6.4 %
FR9	3 / 4	+8.0 %	-11.0 %	+6.7 %
LM10Tselfed	2 / 5	+8.7 %	-18.2 %	+6.9 %
LM238TxLM511P	1 / 5	+5.9 %	+24.6 %	+7.1 %
LM426Tselfed	1 / 2	+4.9 %	+35.9 %	+7.0 %
LM430T selfed	1 / 1	+3.4 %	+26.2 %	+4.9 %
LM5Tselfed	5 / 11	+6.6 %	-17.9 %	+4.9 %
LM5TxLM10T	4 / 9	+9.6 %	-21.8 %	+7.5 %
LM718TxLM238T	1 / 5	+8.2 %	+25.5 %	+9.3 %

2.5. Iodine value

The Iodine value (IV) is an estimation of the unsaturated fatty acid content in vegetable oil. The higher the value, higher the content in unsaturated fatty acid. The iodine value of palm oil is around 50 – 58. The position of CPO on average, compared to other vegetable oils, is specified in Table 30.

Table 30: Iodine value of some vegetable oils (adapted from Meunier and Boutin, 1975)

Type of vegetable oil		Iodine Value
Elaeis guineensis	CPO	50 – 58
	PKO	12 – 19
Elaeis oleifera		82 – 85
Olive oil		82 – 85
Sunflower oil		120 – 134
Soya oil		125 - 138

2.5.1. Family evaluation

On family level, in the A Group, all the three families derived from LM404D have an excellent iodine value, improving the mean of the project by 4.3 % to 56.1. In the Group B families, as expected the best improvement is recorded for La Mé families such as LM5T x LM2T (+3.5 %), LM2T second cycle (+2.1 %) or the recombination with Congo (Sibiti) (+2.6 %). The amplitude of the fluctuation appears to be larger in the Pobé group (Table 31).

2.5.2. Parents from the PSBB Group

In the PSBB Group, all the A Group parents improving the Iodine Value come from BB126D x BB150D (Table 32). With 2.3% of progress on average, the best Iodine Value reaches 53.8 only. It is insufficient to compete with other parents, particularly those from the Pobé group.

The best Group B parents come from the La Mé origin as expected: 5 parents, 2 from LM2T selfed, 2 from LM5T x LM2T and BB106T (LM2T x LM269D) have a good GCA potential with 4.3 % of potential progress.

2.5.3. Parents from the Angola origin test group

The best GCA (%) recorded in the Angola origin test group increases 4.4 % and 5.2 % in the Group A and the Group B families respectively (Table 33).

2.5.4. Parents from the Pobé group

From the Pobé group, 7 Group A parents and 11 parents from Group B have a significant good GCA for the Iodine value (Table 34). The parents are improving the group mean by 4.8 % and 4.4 % respectively. For the A Group of parents, six out of seven parents have LM404D as an ancestor. In the Group B, the best parents mainly come from La Mé origin (9 parents).

The recombination La Mé x Sibiti (LM2T x SI10T) appears interesting for the Iodine Value improvement with 33% of outstanding parents.

Table 31: Average iodine values in the analysed groups

	General mean	PSBB Group	Angola Group	Pobé group
Iodine value	53.8	53.1	55.2	54.5
	Minimum	49.9	52.7	49.2
	Maximum	55.5	58.1	58.7

Table 32: Iodine Value characteristics in the PSBB Group (GCA %)

High Iodine Value			Low Iodine Value		
A Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
BB126DxBB150D	4 / 9	+2.3 %	BB177DxBB129D	2 / 3	-2.8 %
			BB206Dselfed	2 / 4	-2.6 %
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
LM2Tselfed	2 / 2	+4.4 %	BB85Tselfed	2 / 5	-3.6 %
LM2TxLM269D	1 / 1	+4.5 %	BB85TxBB20P	2 / 3	-3.0 %
LM5TxLM2T	2 / 3	+4.0 %	PO1879TxPO1876T	1 / 5	-6.1 %

Table 33: Iodine Value characteristics in the Angola origin test group (GCA %)

High Iodine Value			Low Iodine Value		
A Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
(TNR115xLM630D)I	3 / 11	+4.4%	(TNR115xLM630D)I	4 / 11	-3.6 %
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
LM2Tselfed	1 / 5	+1.7 %	LM2TxLM5T	2 / 6	-1.6 %
LM2TxLM5T	1 / 6	+5.2 %			

Table 34: Iodine Value characteristics in the Pobé group (GCA %)

High Iodine Value			Low Iodine Value		
A Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
(DA5DxDA3D)selfed	1 / 16	+5.2 %	DA10DxDA115D	1 / 8	-3.4 %
LM404Dselfed	3 / 5	+4.4 %	DA115Dselfed	1 / 9	-3.7 %
LM404DxDA10D	2 / 6	+4.5 %	DA115DxDA3D	2 / 7	-5.4 %
LM404DxDA3D	1 / 9	+5.0 %	DA551DxDA767D	1 / 7	-6.2 %
			LM269DxDA115D	1 / 8	-4.3 %
			LM269DxDA128D	1 / 16	-7.0 %
B Group					
Family	Parents	GCA (%)	Family	Parents	GCA (%)
(LM2TxSI10T)I	2 / 6	+5.0 %	LM238TxLM511P	3 / 5	-6.1 %
FR9	1 / 4	+3.5 %	LM2TxLM231T	1 / 4	-9.7 %
LM10Tselfed	2 / 5	+3.8 %	LM430T selfed	1 / 1	-6.1 %
LM2Tselfed	1 / 18	+6.6 %	LM5Tselfed	2 / 11	-5.5 %
LM2TxLM5T	3 / 12	+4.2 %	LM5TxLM10T	1 / 9	-4.2 %
LM5Tselfed	2 / 11	+3.5 %	LM5TxLM311P	2 / 6	-4.0 %
			LM718Tselfed	1 / 1	-5.1 %
			LM718TxLM238T	2 / 5	-7.0 %

2.6. Yield

The GCA evaluation will be concentrated on the following characteristics in the mature period:

FFB 6 to 9- years -old (converted to tonnes/ha)

CPO 6 to 9- years -old (t/ha)

Total Oil 6 to 9- years -old (t/ ha)

2.6.1. Family evaluation

The standard cross confirms under Indonesian conditions the general well-known performance: high FFB and relatively low CPO/ha. While the project mean reaches 87% of the standard cross in terms of FFB, it is compensated for a better extraction rate, as explained above.

Table 35: Yield characteristics for the standard cross and the project mean

	LM2T x DA10D	ALT project
FFB 6_9	32.353	28.230
CPO 6_9	7.273	7.364
TO 6_9	7.891	7.915

Table 36 summarizes the general yield characteristics of the study groups.

Within the A Group, two families have an outstanding GCA for the Total Oil produced: LM404D selfed and DA551D x DA767D with 8.3 and 9.0 tonnes Total Oil/ha/year respectively. For the first, the relatively low FFB (-2.2 %) is largely compensated for the extraction rate. The improvement in terms of CPO reaches 6.4 % and 4.4 % in terms of Total Oil produced. The lower improvement for the last characteristic is due to a small kernel.

DA551D x DA767D, which is a new and very interesting family, has a good GCA for the FFB (+8.2 %) due to an excellent bunch number. The improvement for CPO amounts to 12.5% and 11.6 % for the Total Oil produced (CPO + PKO).

From the B Group, 6 families, all of La Mé origin, have a significant GCA for the Total Oil produced (+5.2 %). The best family, LM426T selfed, represented by 2 pisifera come from Congo (Yangambi). The GCA for the total Oil produced for this family reaches 6.6 %.

A high bunch number, high oil extraction rate and small kernel are the confirmed characteristics of the 6 La Mé families.

2.6.2. Parents from the PSBB Group

From the deli group, only 1 parent out of 16 displays a significant positive GCA (Table 37). The improvement remains low with 4.3 % for CPO and 3.7 % for the total oil produced. The expected improvement is greater for the Group B parents, from 7.3 to 10.7 % in total oil. The number of outstanding parents increases to 9 out of 24. The parents come from two La Mé families, one Congo (Yangambi) family and the Nifor family. In this group, a large share of the improvement comes from the increase in FFB except for the parents derived from LM718T x LM238T. The ratio of good parents reaches 25% in this group.

2.6.3. Parents from the Angola origin test group

Only 1 Angola x Deli parent has a good GCA (Table 38). The improvement is virtually shared at 50% from FFB and 50% from the extraction rate. The origin of the improvement is contrasting for the La Mé partners. For the first, the improvement comes from the FFB and for the second, from the extraction rate. The ratio of good parents reaches 14%.

2.6.4. Parents from the Pobé group

The population of tested parents is much larger in the Pobé group. Ten parents from the A Group and 18 parents from the B Group have a good GCA (Table 39). The corresponding families can be divided into two parts according to the origin of the improvement:

Improvement mainly from FFB: DA10D x DA3D, DA551D x DA767D, LM404D x DA10D, (LM2T) II, LM2T selfed, LM2T x LM10T, LM2T x LM5T; i.e. 39% of the best parents and 4.9 % of the tested parents.

Improvement mainly from extraction rate: DA115D selfed, LM269D x DA128D, LM404D selfed, (LM2T x SI10T) I, FR9, LM10T selfed, LM5T selfed, LM5T x LM10T; i.e. 61 % of the best parents and 7.6 % of the tested parents.

Except for a few cases, the total oil improvement ratio is lower than the CPO improvement ratio. This underlines our comment in the bunch quality section regarding the switch of a share of KO/Bi to O/Bi due to a smaller kernel.

Table 36: General yield characteristics of the studied groups

	General mean	PSBB Group	Angola Group	Pobé group
FFB 6_9	28.230	28.052	32.408	28.841
	Minimum	24.581	29.998	23.815
	Maximum	31.849	35.541	34.068
CPO 6_9	7.364	7.324	7.478	7.544
	Minimum	6.359	6.932	6.381
	Maximum	8.416	8.131	8.768
TO 6_9	7.915	7.841	8.412	8.081
	Minimum	6.975	7.909	6.891
	Maximum	8.756	9.072	9.302

Table 37: Mean of the GCA of the best parents from the PSBB Group

Family	Parents	FFB	CPO	Total Oil
A Group				
BB126DxBB150D	1 / 9	+4.4 %	+4.3 %	+3.7 %
B Group				
PO1879TxPO1876T	3 / 9	+8.6 %	+13.5 %	+10.7 %
LM718TxLM238T	3 / 5	+2.2 %	+6.6 %	+7.3 %
LM5TxLM2T	1 / 3	+13.1 %	+10.4 %	+10.2 %
LM2Tselfed	2 / 2	+12.1 %	+6.0 %	+8.6 %

Table 38: Mean of the GCA of the best parents from the Angola origin test group

Family	Parents	FFB	CPO	Total Oil
A Group				
(TNR115xLM630D)I	1 / 11	+3.7 %	+8.7 %	+7.8 %
B Group				
LM2Tselfed	1 / 5	+9.7 %	+5.7 %	+6.8 %
LM2TxLM5T	1 /6	-4.2 %	+6.3 %	+4.0 %

Table 39: Mean of the GCA of the best parents from the Pobé group

Family	Parents	FFB	CPO	Total Oil
A Group				
DA10DxDA3D	1 / 7	+4.0 %	+6.0 %	+4.9 %
DA115Dselfed	1 / 9	+2.4 %	+5.5 %	+3.7 %
DA551DxDA767D	3 / 7	+12.1 %	+12.7 %	+13.1 %
LM269DxDA128D	2 / 16	+4.8 %	+8.7 %	+9.3 %
LM404Dselfed	2 / 5	+1.0 %	+10.6 %	+8.7 %
LM404DxDA10D	1 / 6	+8.3 %	+11.3 %	+9.8 %
B Group				
(LM2T)II	2 / 8	+7.0 %	+11.3 %	+10.4 %
(LM2TxSI10T)I	1 / 6	-1.3 %	+8.3 %	+6.5 %
FR9	1 / 4	+2.8 %	+7.8 %	+6.7 %
LM10Tselfed	3 / 5	+1.9 %	+9.2 %	+7.4 %
LM2Tselfed	1 / 18	+8.3 %	+11.0 %	+9.3 %
LM2TxLM10T	2 / 8	+7.1 %	+7.1 %	+5.9 %
LM2TxLM5T	1 / 12	+5.0 %	+5.8 %	+5.3 %
LM5Tselfed	4 / 11	+2.4 %	+10.0 %	+8.7 %
LM5TxLM10T	3 / 9	+3.0 %	+11.9 %	+9.7 %

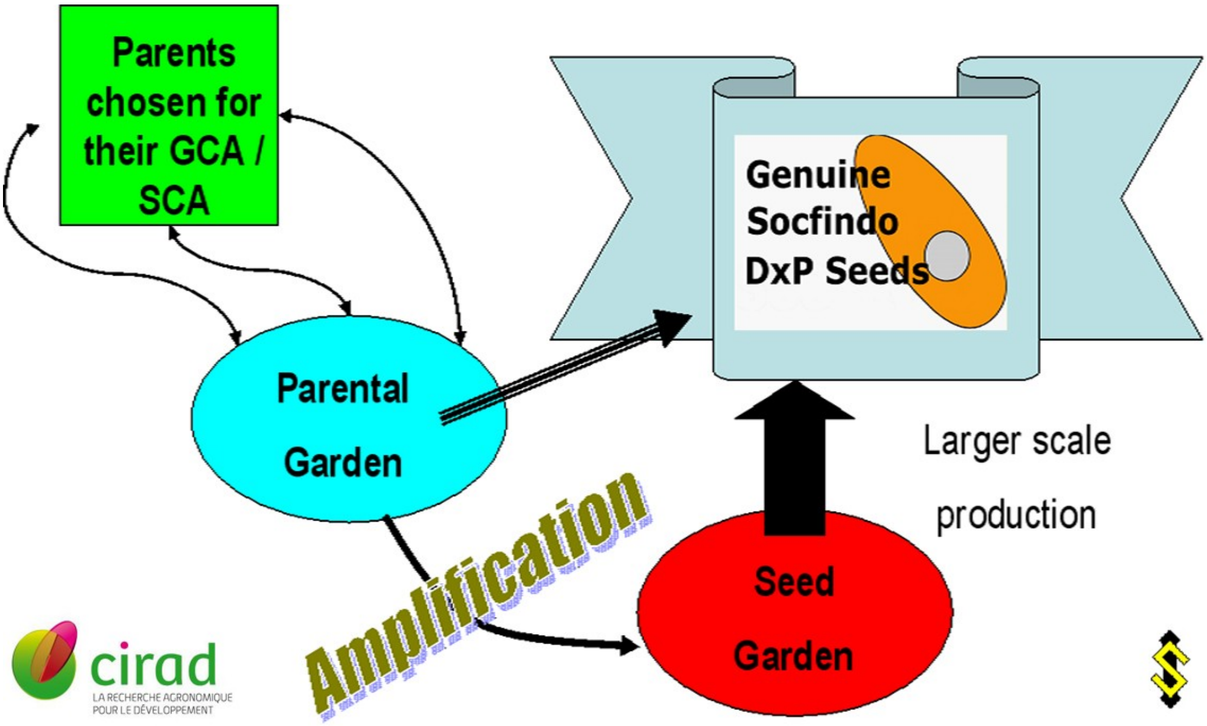
3. Transfer to the commercial plantation

3.1. Introduction

Progress is transferred by exploiting the General Combining Ability results as shown above by using of the selfings of the best parents or the sib-crosses between them from each group. The method allows the exact reproduction of the quality and the potential of the selected progenies and parents (Gascon *et al.*, 1981; Jacquemard *et al.*, 1981). The basic scheme is summarized in the figure 1. It is undertaking the third and fourth steps of the PT Socfindo strategy for profitability as reiterated below:

- Creation and maintenance of genetic resources
- Permanent variety creation
- Continuous exploitation of the creation
- Non-stop improvement of seed production

Figure 1: Principle of the transfer of breeding improvements to commercial seed (adapted from Baskett *et al.*, 2008)



3.2. Seed production

PT Socfindo commercial seed production is based on two types of genetic resources:

The mother palms originate from Deli Socfindo, Deli Socfin (Malaysia) and Deli Dabou (Côte d'Ivoire). The pollen source i.e. the pisifera, come from La Mé (Côte d'Ivoire) and Congo Yangambi.

The main seed garden is located at the Bangun Bandar Estate and covers 211 ha. 5199 Elite Mother Palms from 191 families and 388 Elite Pisifera from 39 families are in use. Another seed garden at the Aek Loba Timur Estate was opened in 2009 within the Aek Kwasan II project. One of the aims of the project is to develop a new seed garden covering 110 ha allowing the production of 40 million germinated seeds.

For the development of the AKII seed garden, the families reproduce the best parents from the Aek Loba Timur Project planted at Bangun Bandar. The parents used in the mating design for amplification were chosen for their bunch quality. This strategy guarantees a further improvement focused on the extraction rate (Table 40). Taking into account the heritability of the components evaluated from the project (Flori, personal communication), the expected improvement amounts to 4.3% for the extraction rate (O/Bi) and 3.0 % for the total oil produced (TO/Bi).

Today, 1902 Elite Mother Palms are already in use in the Aek Kwasan II seed garden. The AKII seed garden should be fully operational by around 2015.

Table 40: Expected improvement due to the amplification strategy

	F/B	M/F	O/M	O/Bi	KO/Bi
Mother palms					
Family mean	67.6	70.9	47.4	19.4	1.99
Chosen parents	69.8	73.3	48.5	21.2	1.87
Tenera palms					
Family mean	61.5	81.9	50.6	21.8	2.03
Chosen parents	64.1	84.2	53.3	24.6	1.86
h^2_{ns}	0.2	0.6	0.4		0.7

According to all the results shown in this paper, the potential of PT Socfindo planting material can be summed as follow:

- Average Fresh Fruit Bunch: 28 – 32 tonnes/ha/year with a potential up to 40 tonnes/ha/year under certain conditions
- Palm oil extraction rate: > 26 % and > 27 % for the material from the AKII seed garden
- Total extraction rate: > 30.2 % and > 31.1 % for the material coming from the AKII seed garden
- Average CPO production: 7 – 9 tonnes/ha/year (7.3 – 9.3 tonnes/ha/year for the AKII seed garden)
- Total palm production reaches 10 tonnes/ha/year (10.3 tonnes for the AKII seed garden)
- The first harvest 24 months after planting reaches 14 – 20 tonnes/ha/year
- Vertical growth limited to around 50 cm/year and an Iodine value > 54

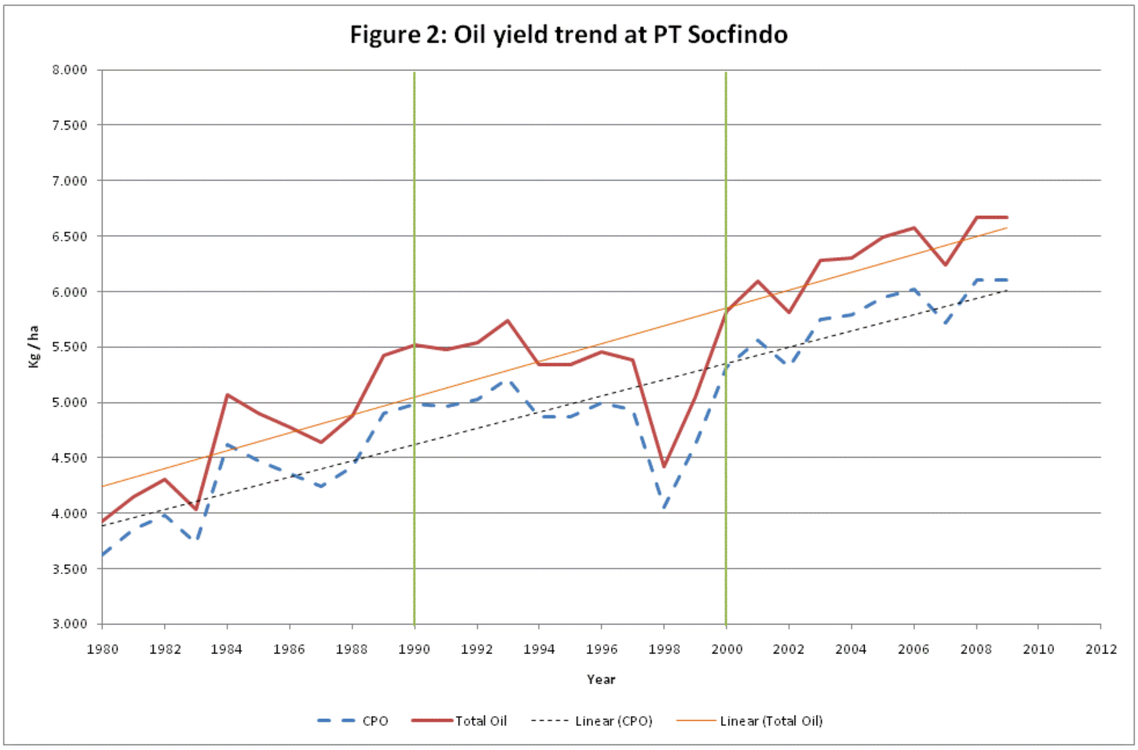
Specifically composed of packages, mixing Deli x La Mé and Deli x Yangambi categories are proposed for areas with the best agro-climatic conditions to mitigate the risk of low male flowering between 3 and 5- years -old.

3.3. Commercial figures

The link between profitability and yield progression has been demonstrated as has the annual yield growth and the large share of genetic improvement arising from that yield growth where the industry has effectively improved its field management and agronomic practices (Baskett *et al.*, 2008).

The following figures (Figures 2 to 4) confirm the real progress on average at PT Socfindo and on some estates such as Aek Loba and Seumanyam.

On average, all generations of planting material combined, production reached 6.1 tonnes CPO and 6.7 tonnes Total Oil on average from all the PT Socfindo estates at the 2009 end. At the Aek Loba Estate in North Sumatra, production reached respectively 6.7 and 7.4 tonnes/ha/year. The figures are 6.8 and 7.4 tonnes/ha/year at the Seumanyam Estate (NAD).



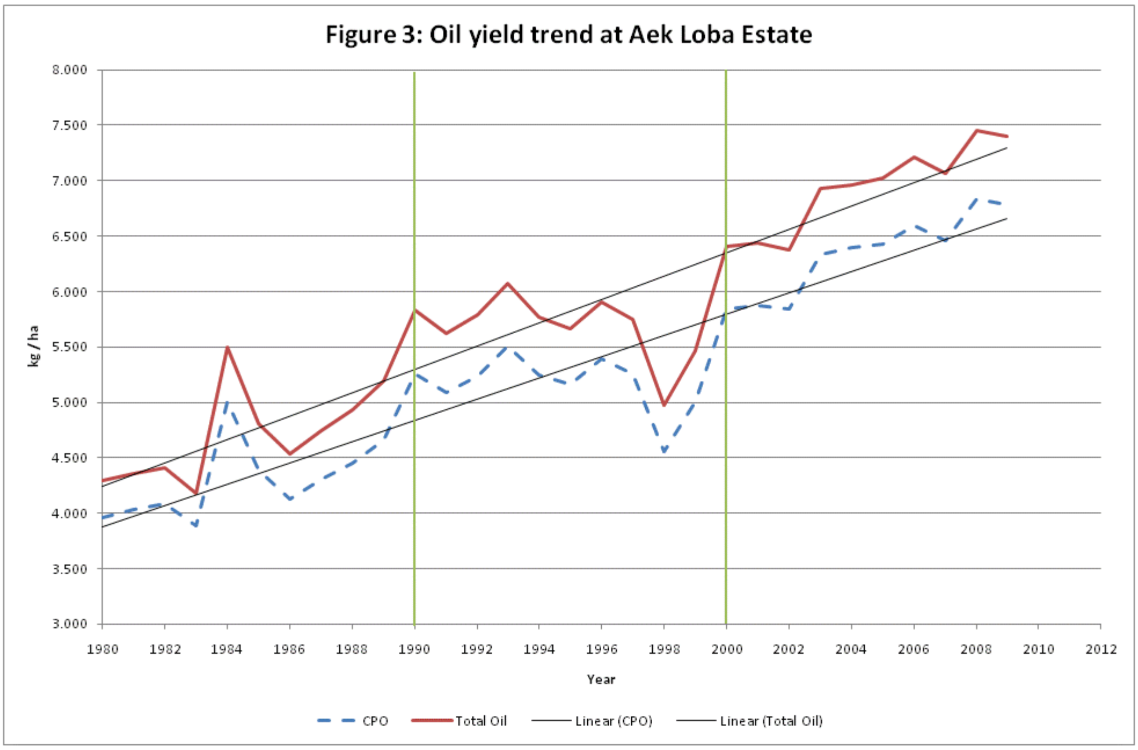


Figure 3: Oil yield trend at Aek Loba Estate
kg / ha
8.000
7.500
7.000
6.500
6.000
5.500
5.000
4.500
4.000
3.500
3.000
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year
CPO
Total Oil
Linear (CPO)
Linear (Total Oil)

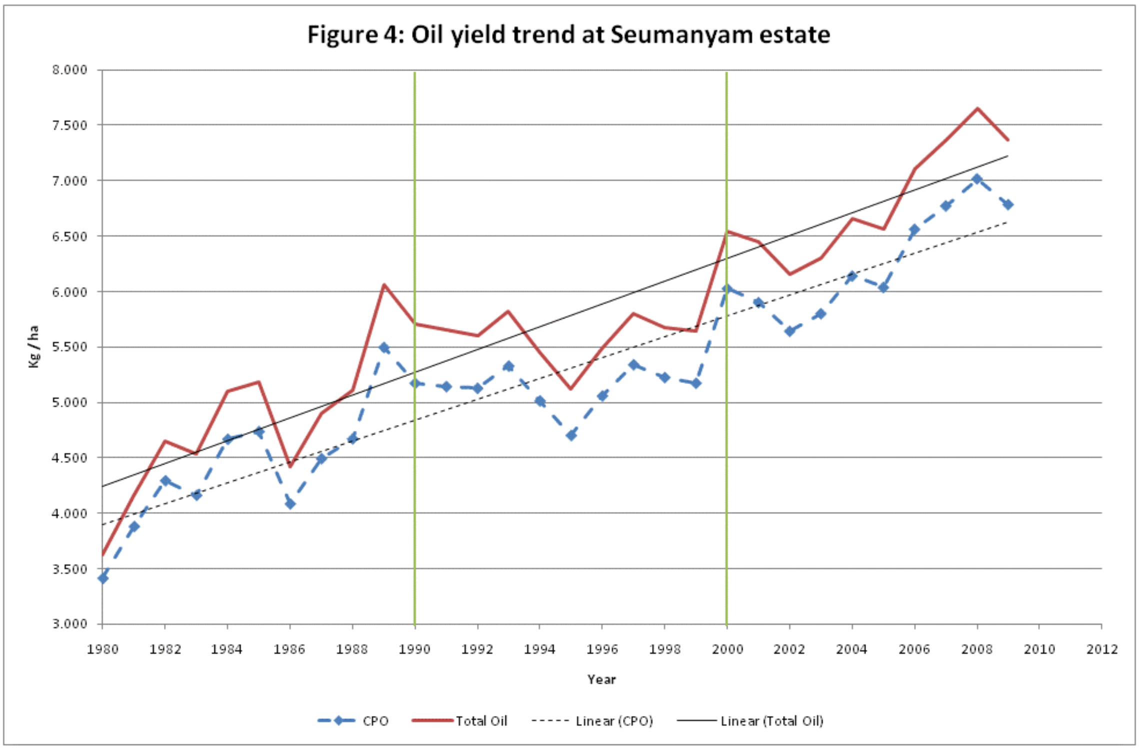


Figure 4: Oil yield trend at Seumanyam estate
Kg / ha
8.000
7.500
7.000
6.500
6.000
5.500
5.000
4.500
4.000
3.500
3.000
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year
CPO
Total Oil
Linear (CPO)
Linear (Total Oil)

4. Challenges and new developments

The challenge for the future remains to achieve more productive planting material with FFB and OER as the corner-stones of the planting material quality (Baskett *et al.*, 2008).

The Aek Loba Timur project is carrying out improvement of the CPO and Total Oil reaching more or less 8 %. The genetic improvement of 1 % per year is achieved for the next 8 years. In 2018, a new step will be required. It should be devoted to the Aek Kwasan II project presented above.

But other characteristics must be considered (Baskett *et al.*, 2008):

- Palms better adapted to specific environmental conditions
- Resistance of various stress factors such as drought, wind, temperature, etc
- Palms better adapted to specific nutrient requirements
- Resistance to specific diseases or pests, such as *Ganoderma*, *Oryctes*, etc.
- Economic considerations
- Downstream or end-user requirements
- Etc.

When summing up the results collected from the Aek Loba Timur project for some of the targeted characteristics of the best parents (Table 41), it is obvious that very few parents can cumulate all the expected characteristics.

Table 41: Example of the additional characteristics of the best parents (PSBB Group)

A Group									
Parent code	Family	TO	PKO	ABW	TO/Bi	IV	MAL	G	AG
D1	DA10DxDA3D		PKO-						AG+
D2	DA115Dselfed		PKO-				Mal+		
D31	DA551DxDA767D	TO+	PKO+				Mal-		
D32		TO+					Mal-		
D33		TO+				IV-			
D41	LM269DxDA128D	TO+	PKO+				Mal-		
D42		TO+		ABW+	TO/Bi+				
D51	LM404Dselfed	TO+	PKO-	ABW-	TO/Bi+				
D52		TO+	PKO-	ABW-	TO/Bi+	IV+			AG+
D6	LM404DxDA10D	TO+	PKO-						AG+
B Group									
Parent code	Family	TO	PKO	ABW	TO/Bi	IV	MAL	G	AG
P11	(LM2T)II	TO+							
T12		TO+			TO/Bi+		Mal-		
P2	(LM2TxSI10T)I	TO+	PKO-		TO/Bi+		Mal+		AG+
P3	FR9	TO+		ABW+		IV+		G+	AG+

P41	LM10Tselfed	TO+	PKO-	ABW-	TO/Bi+		Mal-		
P42		TO+	PKO-		TO/Bi+	IV+			
T43			PKO-			IV+		G+	
T5	LM2Tselfed	TO+							
P61	LM2TxLM10T		PKO-	ABW-				G+	AG+
P62		TO+							
P7	LM2TxLM5T	TO+					Mal-		
P81	LM5Tselfed	TO+		ABW+					AG+
P82		TO+			TO/Bi+	IV-			
T83		TO+			TO/Bi+				
T84		TO+	PKO-	ABW-	TO/Bi+	IV-			
P91	LM5TxLM10T	TO+	PKO-	ABW+	TO/Bi+		Mal+		AG+
P92		TO+	PKO-		TO/Bi+				AG+
P93		TO+	PKO-	ABW-					

In our example, the evaluated characteristics are: TO (Total Oil/ha/year), PKO (Palm Kernel Oil/ha/year), ABW (Average Bunch Weight), TO/Bi (Total Oil commercial extraction rate), IV (Iodine Value), Mal (Male inflorescence density / ha), G (% of *Ganoderma*) and AG (Annual Growth). The code "+" specifies that the parent is significantly better than the mean of the project. Conversely, the code "-" indicates a parent significantly lower than the project mean. The absence of any indication in the box implies a parent that does not differ from the mean.

Tracking the required qualities within the families or parents and monitoring recombination through the traditional methods such as field observations and bunch analyses, is a very lengthy process. All breeders experience that.

In the near future, the oil palm industry will be facing several key facts i.e. replanting of the first boom of oil palm planted in the 1980s, the effect of global warming and the probable scarcity and increase in the price of fertilizers.

The first fact means that a planting material will soon have to be prepared that is resistant to *Ganoderma* as part of the integrated control of the disease, the second means improving our knowledge on genetic x environment interactions and the third means proposing a planting material that is less demanding in fertilizers.

Breeding for *Ganoderma* resistance is a major target of the Research & Development programmes at PT Socfindo. Recent results prove the feasibility and the efficiency of the early screening test developed in 2005 by Sumatra Bioscience, PT Socfindo and CIRAD (Breton *et al.*, 2005; 2009). The first indications collected underline a good correlation between the screening test data and the *Ganoderma* percentage observed in the field. A new approach is currently being explored through the development of molecular markers and genomic studies (Breton *et al.*, 2010).

The high degree of genotype x environment (GxE) interaction makes it difficult to assess the causal relationship between genotype and phenotype. Thus, adaptation to abiotic stresses or exploitation of genetic signature of the mineral nutrition to produce planting material adapted to future agro-climatic conditions and scarcity of fertilisers require an answer within 10 to 15 years (Rival and Jaligot, 2010; Jacquemard *et al.*, 2009). New biotechnology tools are under development and should be available soon such as the deciphering of the oil palm genome, genetic mapping through microsatellite markers, DNA ships analyses, epigenetic mechanisms, the methods for transcriptomic, proteomic, metabolomic and ionomic analyses (Rival and Jaligot, 2010).

If we keep in mind that with traditional tools, from the choice of the first parent in a progeny trial, 16 to 20 years will go fly before the breeder can propose the first delivery of seeds arising from it (Baskett *et al.*, 2008); these new tools and analyses appear essential for achieving the target assigned to the oil palm industry.

CONCLUSION

PT Socfindo and its partner CIRAD are making very large investments in Research & Development for breeding to support the production of high quality planting material. Today, up to 790 ha have been devoted to collection and variety creation, 490 ha to field test and a Phytopathology Unit carrying out screening tests in breeding for *Ganoderma* resistance and 269 ha for current and future seed gardens.

Under North Sumatran conditions, the potential of PT Socfindo planting material should reach 10 tonnes of total oil (CPO + PKO) and there are greater expectations for the new Aek Kwasan II seed garden.

The major challenge for the future is to combine high FFB and bunch quality in Total Oil / ha and numerous other characteristics expected by the oil palm industry. It is well known that 16 to 20 years go by from the first choice of the first parent in a progeny trial and the delivery of the first seeds arising from it. This is to that 2028 is tomorrow for oil palm breeders.

Addressing the threat of global warming, replanting the first oil palm boom, future scarcity in energy and fertilisers are pointing to a shorter dead-line. The quick introduction of new biotechnology tools such as the deciphering of the oil palm genome, genetic mapping through microsatellite markers, DNA ships analyses, epigenetic mechanisms, methods for transcriptomic, proteomic, metabolomic and ionomic analyses is essential for maintaining the target of 1% of genetic improvement per year.

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